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SYNOPSIS

ON

"Study on synthesis, characterization and potential applications of Fluorescent nanomaterials from *Lantana camara* and *Porana paniculata*".

(For the Award of Ph.D. Degree in the Faculty of Science)

[Botany]

Submitted to:

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Introduction:

Carbon quantum dots are quasispherical nonmaterials that range in size from 1 to 10 nm and hold a variable number of electrons [Kuchibhatla et al., 2007; Koole et al., 2014]. QDs absorb and emit light at different wavelengths, and the emitted colour is determined by their dimensions and material composition. Changing the size of QDs changes their fluorescence, meaning they can be changed to produce different colours. The smaller the nanoparticle, the narrower the wavelength and emits blue light, while a larger nanoparticle has a broader wavelength and emits red light. Due to their excellent physiochemical properties, QDs have a wide range of applications in electronic devices, including computer monitors, TV displays (QLED), solar panels, solar cells, medical fields such as light-based therapeutics, diagnostics (highlighting the organs or tumours in a patient's body), sensing of heavy toxic metal ions or chemicals, drug delivery, cell imaging, antimicrobial activity, etc [Thokchom et al., 2023; Shen et al., 2012; Pleskova et al., 2018; Mazumder et al 2009; Peng & Li, 2010; Lai et al., 2017].

Review of literature:

In the early 1980s, researchers began investigating semiconductor particles, and for the first time, Alexey Ekimov experimentally observed the quantum particle cadmium selenide (CdSe) by conventional methods [Ekimov A.I., 1981]. Recently, in 2023, Alexei Ekimov, Louis Brus, and Moungi Bawendi were awarded the Nobel Prize for their discovery and synthesis of QDs. During the last decade, many of the research groups have synthesized QDs using various methodologies such as chemical oxidation, arc discharge, laser ablation, hydrothermal, and microwave irradiation. As well as characterizing the carbon dots, they examine their size, shape, composition, and optical properties by using various techniques like transmission electron microscopy (TEM), x-ray diffraction (XRD), x-ray photoelectron spectrophotometer (XPS), fourier-transform infrared spectroscopy (FTIR), UV-Vis, and florescence spectroscopy. Characterization of CQDs helps in understanding their properties and optimizing them for specific applications.

QDs have many noble physicochemical properties, such as tunable excitation emission properties, broad excitation spectra, low-cost synthesis, less toxicity, good membrane permeability, biocompatibility, eco-friendliness, excellent water solubility, and easy surface functionalization ability [Hu et al., 2014]. Due to this valuable property, QDs are used in various fields of biology, such as fluorescence resonance energy transfer (FRET), gene technology, fluorescent labelling, cellular tracking, bio-imaging, drug delivery, and the sensing of heavy toxic metal ions and biomolecules for early cancer detection in humans, etc.

Over the last decades, there has been extensive research on QDs and their applications. Many chemically synthesized QDs showed good antimicrobial activity. Like, cadmium-based QDs (CdQDs) produce reactive oxygen species (ROS) when exposed to light and cause oxidative damage to bacterial cells [Lai et al., 2017]. But chemically synthesized QDs like CdQDs and others have several harmful effects and compatibility issues with biological systems. Many researchers still follow the conventional methods, which involve using heavy toxic metals like cadmium, lead, zinc, etc. to prepare QDs, which can be hazardous to both the human body and the environment, as well as being a time consuming process.

At present, several research groups have utilized green precursors such as *Polyalthia longifolia* (Kolaprath et al., 2023), *Tagetes patula* (Patra et al., 2023), *Phoenix dactylifera* (Athinarayanan et al., 2023), *Centella asiatica* (Thokchom et al., 2023), *Stachys euadenia* (Baslak et al., 2024), *Osmium sanctum, Prunus persica,* etc. for the synthesis of fluorescent carbon quantum dots. These fluorescent nanoparticles (CQDs) have various applications such as sensing of toxic metal ions, cellular bioimaging, drug delivery, therapeutics, and tumor biology research-multicolor imaging [Azzazy et al., 2007; Cai et al., 2006; Gao et al., 2005; Medintz et al.,2005]. These naturally synthesized CQDs have negligible cytotoxicity but good biocompatibility. Toxic metal ions are released from various industries in the aquatic system, and they accumulate in the food chain. These heavy metals are highly toxic and have serious effects on the liver, kidney, cardiovascular, and central nervous systems. They are also carcinogenic for the human body [Singh et al., 2019].

As a result, naturally derived CDs are a good candidate for sensing toxic metal ions and for cellular imaging. Our aim is to synthesize fluorescent nanoparticles (carbon quantum dots) using a green synthesis approach using hydrothermal methods that are eco-friendly and non-toxic to humans and the environment by utilizing a green precursor approach, particularly plants (*Lantana camara, Porona paniculata, Moringa, Calotropis*, etc.) and their different parts.

Objectives:

1. To explore various plant-based sources and optimization of synthesis process.
2. Characterization of the synthesized nanomaterial's (CQDs) using different techniques.
3. Sensing of toxic metal ions using the green synthesized fluorescent nanomaterials.
4. Screening of synthesized fluorescent nanomaterials for cellular toxicity and bioimaging.

Methodology & Plan of Work:

1. Plant species (*Lantana camara, Porona paniculata, Moringa, Calotropis*, etc.) will be screened for their potential to synthesize fluorescent nanomaterials (CQDs). Factors such as availability, bioactivity, and sustainability will be considered.
2. Green synthesis of fluorescent carbon quantum dots (carbon nanoparticles) following the procedure adopted by Singh et al., 2019.
3. Different parameters, including temperature, pH, and reaction time, will be optimized.
4. The absorption spectra, fluorescence emission spectra, quantum yield, photostability, size, and morphology of the synthesized nanomaterials will be investigated using UV-Vis spectrophotometers, fluorescence spectrophotometers, FTIR, XRD, XPS, TEM, etc.
5. The cytotoxicity of synthesized fluorescent quantum dots on HEK-293 cells will be screened using the Alamar Blue assay.
6. The detection of metal ions will be carried out by preparing a stock solution of 0.01 M of different metal solutions in 10 mL of distilled water. The desired concentration of metal ions will be obtained through serial dilution of the stock solution.
7. The fluorescence titration spectra will be recorded in both the absence and presence of different concentrations of metal ions in CQDs.
8. The limit of detection will be calculated using the formula $3\sigma/m$, where σ is the standard deviation and m is the slope of the (F0/F Vs C) graph. The interference of other metal ions will be checked in a similar manner.
9. The cellular uptake of the carbon quantum dots in HEK-293 cells will be observed using fluorescence microscopy.

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